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LIQUID CRYSTAL DISPLAY DEVICE AND METHOD FOR DRIVING THE SAME

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION:

The present invention relates to a matrix type super twisted nematic (STN) liquid crystal display device and a method for driving the device. The device and method are used in office automation equipment such as a personal computer and word processor, multi-media personal digital assistants, audio and video equipment, game machines, and the like. More particularly, the present invention relates to a liquid crystal display device and a driving method therefor which can improve display quality.

2. DESCRIPTION OF THE RELATED ART:

Conventional STN liquid crystal display (LCD) devices have a problem that as display capacity, such as liquid crystal capacity is increased, display irregularity depending on display patterns emerges, leading to a significant decrease in display quality. Such display irregularity is called crosstalk.

An example of such crosstalk is one caused by induced distortion of scanning voltage (hereinafter referred to as "induced distortion crosstalk").

Specifically, when the waveforms of signal voltages applied to a number of column electrodes are simultaneously changed, a high level of induced distortion occurs in scanning voltage, so that an effective voltage value applied to each pixel is increased or decreased to be shifted from an intended effective voltage value.

Figure **14A** is a diagram used to briefly explain induced distortion crosstalk, showing a liquid crystal panel **140** including row electrodes **Y1** through **Y4** and column electrodes **X1** through **X4**. When signal voltages **SG1** through **SG4** having waveforms shown in Figure **14B** are applied to the column electrodes **X1** through **X4** of Figure **14A**, induced distortion **S1** through **S4** occurs in the scanning voltage on the row electrode **Y1** as shown in Figure **14C**. Similar induced distortion occurs in the scanning voltage on the row electrodes **Y2** and **Y3**.

The magnitudes of induced distortion **S1** through **S4** occurring in the scanning voltage on the row electrode **Y1** vary depending on the number of signal voltages **SG1** through **SG4** which are simultaneously changed.

The more signal voltages simultaneously changed in the same direction, the larger the magnitudes. As shown in Figures **14B** and **14C**, when signal voltages which are changed in opposite directions cancel one another, smaller induced distortion occurs in a row electrode (**S3** in Figure **14C**) as compared to when signal voltages are changed in the same direction (**S1**, **S2** and **S4** in Figure **14C**).

To solve the above-described problems, for example, Japanese Laid-Open Publication No. 6-27899 proposes a first conventional technique in which a change in voltage on a row electrode is detected and, in response to the change, a voltage on a column electrode is adjusted so that display irregularity is overcome.

Alternatively, Japanese Laid-Open Publication No. 11-84342 proposes a second conventional technique in which display data D(n) on an n^{th} scanning line is compared to display data D(n-1) on an $(n-1)^{th}$ scanning line so that {M(HL)-M(LH)} is calculated where M(HL) is the number of data which transit from an H (High) level to an L (Low) level and M(LH) is the number of data which transit from the L level to the H level, and then a correction voltage

having a magnitude and a direction corresponding to the calculation result is added from a column electrode to a signal voltage so as to correct the signal voltage.

Further, Japanese Laid-Open Publication No. 11-52326 proposes a third conventional technique in which a correction period equal to one or two horizontal scanning periods is inserted every a predetermined number of horizontal scanning periods.

Another type of crosstalk is now described. When the signal voltages **SG1** through **SG4** applied to the column electrodes **X1** through **X4** becomes "blunt" with respect to ideal waveforms due to resistance components of electrodes or capacity components of a liquid crystal layer in a liquid crystal panel, crosstalk (hereinafter referred to as "blunt waveform crosstalk") occurs.

There is also a phenomenon where there is a difference in brightness in the lateral direction of a screen independent of display patterns (hereinafter referred to as the "gradation phenomenon"). This is because a decrease in voltage occurs along a row electrode due to a resistance component of the row electrode and

therefore a difference in an effective voltage value applied to a liquid crystal layer develops with respect to the lateral direction along the row electrode.

In fact, the above-described induced distortion crosstalk varies in a lateral direction along a row electrode due to both the capacity of a liquid crystal layer and the resistance of a row electrode.

Figure **15** shows a difference in induced distortion crosstalk in a lateral direction along a row electrode. As shown in Figure **15**, for example, when the column electrodes **X1** through **X4** simultaneously transit from an H level to an L level, induced distortion **V1** through **V4** occurs in some row electrode **Yn** due to capacities **C1** through **C4** and resistances **R1** through **R4** of the row electrode **Yn**.

In this case, the resistances **R1** through **R4** are connected in series to the column electrodes **X1** through **X4**, respectively. The magnitude of the above-described induced distortion is gradually increased toward the right side, i.e., the above-described induced distortion crosstalk becomes larger at the further right side of the

row electrode **Yn** as shown in Figure **15**.

In the first conventional technique, the induced distortion crosstalk can be corrected. Such correction is performed in response to a change in voltage on a row electrode. In practice, the correction is only performed on a column-driver-by-column-driver basis where each column driver typically controls about 100 or more column electrodes. For this reason, differences in the induced distortion crosstalk in a lateral direction along a row electrode cannot be completely corrected. Thus, the above-described induced distortion crosstalk cannot be optimally corrected.

The second conventional technique makes an attempt to correct differences in induced distortion crosstalk in a lateral direction along a row electrode by digitally detecting the amount of the correction to be made. In practice, circuit scale is disadvantageously increased so that differences in the above-described induced distortion crosstalk can be corrected and smoothed. In order to perform the correction without an increase in circuit scale, the correction is only performed on a column-driver-by-column-driver basis.

The differences in the induced distortion crosstalk in the lateral direction along a row electrode cannot be completely corrected. Similar to the first conventional technique, the induced distortion crosstalk cannot be optimally corrected. Moreover, since the correction is performed every horizontal scanning period, a large error is introduced to an optimal correction.

Further, in the third conventional technique, a correction period equal to one or two horizontal scanning periods is inserted every predetermined number of horizontal scanning periods. Therefore, a small error is only introduced to an optimal correction. However, the set pulse width or pulse amplitude of a correction voltage cannot be changed in small steps. Similar to the first and second conventional techniques, differences in induced distortion crosstalk in a lateral direction along a row electrode cannot be corrected, and therefore the induced distortion crosstalk cannot be corrected.

SUMMARY OF THE INVENTION

According to one aspect of the present invention, a method is provided for driving a liquid crystal display

device including a plurality of row electrodes and a plurality of column electrodes, a scanning voltage being applied to each of the plurality of row electrodes, a signal voltage being applied to each of the plurality of column electrodes, and the plurality of row electrodes intersecting the plurality of column electrodes. The method comprises the steps of: a) determining, for each of the plurality of column electrodes, correction data for correcting the signal voltage based on an increment or decrement of an effective voltage value between each of the plurality of row electrodes and the plurality of column electrodes; and b) applying a correction voltage for correcting the signal voltage to each of the plurality of column electrodes in accordance with the correction data. An increment or decrement of the effective voltage value includes at least either of i) an increment or decrement of an effective voltage value due to at least either a blunt waveform or induced distortion of the signal voltage or ii) an increment or decrement of an effective voltage value due to at least either a blunt waveform or induced distortion of the scanning voltage.

In one embodiment of this invention, the correction voltage is applied to each of the plurality

of column electrodes in a correction period, and the correction period equal to m horizontal scanning periods is provided in L horizontal scanning periods where L is an integer greater than or equal to 2 and m is an integer more than 0 and less than L.

In one embodiment of this invention, the correction data is determined based on a position of each of the plurality of column electrodes.

In one embodiment of this invention, step a) further comprises the step of: c) detecting a change in the signal voltage applied to each of the plurality of column electrodes as a digital amount and outputting the digital amount to each of the plurality of column electrodes.

In one embodiment of this invention, an increment or decrement of the effective voltage value is an increment or decrement of an effective voltage value due to induced distortion of the scanning voltage, and step c) further comprises the step of detecting, for each of the plurality of column electrodes, a change in the signal voltage based on a row driver control signal, and n^{th} row

display data and $(n-1)^{th}$ row display data.

In one embodiment of this invention, step c) further comprises the step of detecting a change in the signal voltage for each of the plurality of column electrodes, and calculating an induced distortion count value representing the total change in the signal voltage over all of the plurality of column electrodes.

In one embodiment of this invention, step a) further comprises the step of: d) calculating, for each of the plurality of column electrodes, an induced distortion correction amount based on the induced distortion count value and a lateral position count value representing a position of each of the plurality of column electrodes in a lateral direction along the plurality of row electrodes.

In one embodiment of this invention, step d) further comprises the steps of: calculating an induced distortion correction variable based on the lateral position count value and a frame number; and calculating the induced distortion correction amount based on the induced distortion correction variable and the induced

distortion count value.

In one embodiment of this invention, the correction voltage is applied to each of the plurality of column electrodes in a correction period, and the correction period equal to m horizontal scanning periods is provided in L horizontal scanning periods where L is an integer greater than or equal to 2 and m is an integer more than 0 and less than L, and step a) further comprises the step of adding or subtracting an error between the correction data and the induced distortion correction amount, the correction data being applied to each of the plurality of column electrodes, to or from an induced distortion correction amount corresponding to a next correction period.

In one embodiment of this invention, an increment or decrement of the effective voltage value is an increment or decrement of an effective voltage value due to a blunt waveform of the scanning voltage, and step c) further comprises the step of detecting, for each of the plurality of column electrodes, a signal voltage change signal based on n^{th} row display data and $(n-1)^{th}$ row display data.

In one embodiment of this invention, the signal voltage change signal includes an n^{th} row signal voltage and an $(n-1)^{th}$ row signal voltage for each of the plurality of column electrodes.

In one embodiment of this invention, step c) further comprises the step of calculating a blunt waveform correction amount for correcting a blunt waveform of the scanning voltage based on the signal voltage change signal.

In one embodiment of this invention, step a) further comprises the step of calculating a gradation correction amount for correcting a gradation phenomenon based on a lateral position count value representing a position of each of the plurality of column electrodes in a lateral direction along the plurality of row electrodes.

In one embodiment of this invention, each correction voltage has a different pulse width.

In one embodiment of this invention, each

correction voltage has a different pulse amplitude.

According to another aspect of the present invention, a liquid crystal display device includes a plurality of row electrodes and a plurality of column electrodes, a scanning voltage being applied to each of the plurality of row electrode, a signal voltage being applied to each of the plurality of column electrodes, and the plurality of row electrodes intersecting the plurality of column electrodes. The device further comprises: a correction operation circuit for determining, for each of the plurality of column electrodes, correction data for correcting the signal voltage based on an increment or decrement of an effective voltage value between each of the plurality of row electrodes and the plurality of column electrodes; and a column driver unit for applying a correction voltage for correcting the signal voltage to each of the plurality of column electrodes in accordance with the correction data. An increment or decrement of the effective voltage value includes at least either of i) an increment or decrement of an effective voltage value due to at least either a blunt waveform or induced distortion of the signal voltage or ii) an increment or decrement of an effective voltage

value due to at least either a blunt waveform or induced distortion of the scanning voltage.

In one embodiment of this invention, the device further comprises a timing control circuit for providing a correction period, wherein the correction voltage is applied to each of the plurality of column electrodes in the correction period, and the correction period equal to m horizontal scanning periods is provided in L horizontal scanning periods where L is an integer greater than or equal to 2 and m is an integer more than 0 and less than L.

In one embodiment of this invention, the correction operation circuit determines the correction data based on a position of each of the plurality of column electrodes.

In one embodiment of this invention, the correction operation circuit comprises a column waveform change detection unit for detecting a change in the signal voltage applied to each of the plurality of column electrodes as a digital amount and outputting the digital amount to each of the plurality of column electrodes.

In one embodiment of this invention, an increment or decrement of the effective voltage value is an increment or decrement of an effective voltage value due to induced distortion of the scanning voltage, and the column waveform change detection unit detects, for each of the plurality of column electrodes, a change in the signal voltage based on a row driver control signal, and n^{th} row display data and $(n-1)^{th}$ row display data.

In one embodiment of this invention, the correction operation circuit comprises a counter for detecting a change in the signal voltage for each of the plurality of column electrodes, and calculating an induced distortion count value representing the total change in the signal voltage over all of the plurality of column electrodes.

In one embodiment of this invention, the correction operation circuit comprises a correction amount look-up table for calculating, for each of the plurality of column electrodes, an induced distortion correction amount based on the induced distortion count value and a lateral position count value representing the

position of each of the plurality of column electrodes in a lateral direction along the plurality of row electrodes.

In one embodiment of this invention, the correction amount look-up table comprises: a look-up table for calculating an induced distortion correction variable based on the lateral position count value and a frame number; and an induced distortion look-up table for calculating the induced distortion correction amount based on the induced distortion correction variable and the induced distortion count value.

In one embodiment of this invention, the correction voltage is applied to each of the plurality of column electrodes in a correction period, and the correction period equal to m horizontal scanning periods is provided in L horizontal scanning periods where L is an integer greater than or equal to 2 and m is an integer more than 0 and less than L, and the correction operation circuit further comprises an adder for adding or subtracting an error between the correction data and the induced distortion correction amount, the correction data being applied to each of the plurality of column

electrodes, to or from an induced distortion correction amount corresponding to a next correction period.

In one embodiment of this invention, an increment or decrement of the effective voltage value is an increment or decrement of an effective voltage value due to a blunt waveform of the scanning voltage, and the column waveform change detection unit detects, for each of the plurality of column electrodes, a signal voltage change signal based on n^{th} row display data and $(n-1)^{th}$ row display data.

In one embodiment of this invention, the signal voltage change signal includes an n^{th} row signal voltage and an $(n-1)^{th}$ row signal voltage for each of the plurality of column electrodes.

In one embodiment of this invention, the correction operation circuit comprises a blunt waveform look-up table for calculating a blunt waveform correction amount for correcting a blunt waveform of the scanning voltage based on the signal voltage change signal.

In one embodiment of this invention, the

correction operation circuit comprises a gradation look-up table for calculating a gradation correction amount for correcting a gradation phenomenon based on a lateral position count value representing the position of each of the plurality of column electrodes in a lateral direction along the plurality of row electrodes.

In one embodiment of this invention, each correction voltage has a different pulse width.

In one embodiment of this invention, each correction voltage has a different pulse amplitude.

Thus, the invention described herein makes possible the advantages of providing: (1) an LCD device and a driving method therefor for correcting and smoothing differences in induced distortion crosstalk in a lateral direction along a row electrode, in which, in the device and method of the present invention, the correction can be achieved without an increase in circuit scale and independent of column drivers and therefore, the induced distortion crosstalk can be optimally corrected with small errors and high precision; and (2) an LCD device and a driving method therefor for correcting the above-described induced distortion crosstalk and at the

same time, optimally correcting blunt waveform crosstalk and a gradation phenomenon.

Hereinafter, functions of the present invention will be described.

In the present invention, a correction voltage for correcting a change in an effective voltage value caused by distortion of a scanning voltage waveform due to a change in signal voltage is applied to each column electrode in a correction period. In this case, the correction period which is equal to m horizontal scanning periods is provided in L horizontal scanning periods where L is an integer greater than or equal to 2 and m is an integer more than 0 and less than L. Thereby, display irregularity caused by the induced distortion crosstalk can be suppressed. Further, in the present invention, a means for generating a correction voltage which is varied every one or more column electrodes is provided. Therefore, differences in the induced distortion crosstalk in a lateral direction along row electrodes as well as the gradation phenomenon can be suppressed. Correction amounts corresponding to (L-m) horizontal scanning periods can be accumulated, thereby reducing a

correction error.

Further, in the present invention, a means is provided for adding or subtracting an error between an increment or decrement of the correction voltage and an increment or decrement of an effective voltage value to or from a correction voltage which will be applied in the next correction period, thereby further improving the precision of correction.

Furthermore, in the present invention, a means for detecting a change in signal voltage applied to one of the column electrodes as a digital amount is provided, thereby detecting a bluntness amount of a signal voltage waveform due to a change in signal voltage. The blunt waveform crosstalk can be suppressed by performing correction corresponding to the bluntness amount in the blunt waveform crosstalk.

These and other advantages of the present invention will become apparent to those skilled in the art upon reading and understanding the following detailed description with reference to the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure **1A** is a diagram showing an example of an LCD device according to Example 1 of the present invention.

Figure **1B** is a flowchart showing an operation of the LCD device of Example 1.

Figure **2** is an input timing chart of a timing control circuit of Example 1.

Figure **3** is an output timing chart of a timing control circuit of Example 1.

Figure **4** is a structure of a correction operation circuit of Example 1.

Figure **5** is an example of an induced distortion look-up table of Example 1.

Figure **6** is an example of an induced distortion correction table of Example 1.

Figure **7** is a graph of induced distortion correction variable (vertical axis) versus count value representing the position of each column electrode in a lateral direction along row electrodes (horizontal axis) in the LCD device of Example 1.

Figure **8** is a table showing a data conversion which is performed in a comparator of Example 1.

Figure **9** is a timing chart showing a waveform of a signal voltage applied to a column electrode in Example 1.

Figure **10A** is a diagram showing an example of an LCD device according to Example 2 of the present invention.

Figure **10B** is a flowchart showing an operation of the LCD device of Example 2.

Figure **11** is a structure of a correction operation circuit of Example 2.

Figure **12** is an example of a blunt waveform

look-up table of Example 2.

Figure **13** is an example of a gradation look-up table of Example 2.

Figures **14A**, **14B**, and **14C** are diagrams used to explain a cause for crosstalk in a conventional LCD device.

Figure **15** is a diagram used to explain a cause for crosstalk in a conventional LCD device.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, the present invention will be described by way of illustrative examples with reference to the accompanying drawings.

(Example 1)

An LCD device and a driving method therefor according to Example 1 of the present invention will be described below, in which induced distortion crosstalk is optimally corrected.

Figure **1A** is a schematic diagram showing an LCD device **100** according to Example 1 of the present invention. Figure **1B** is a flowchart showing an operation of the LCD device **100**. The LCD device **100** includes a timing control circuit **1**, a correction operation circuit **2**, a selector circuit **3**, a power source circuit **4**, a row driver unit **5**, a column driver unit **6**, and a liquid crystal panel **7**.

The timing control circuit **1** controls the timing of the entire system of the LCD device **100**. The timing control circuit **1** receives a synchronization signal **S102** and display data **S101** and outputs a column driver control signal **S203**, display data **S201**, and a row driver control signal **S202**.

The timing control circuit **1** also generates a correction period required for performing correction processing described below, and controls the correction operation circuit **2** and the selector circuit **3**.

Further, the timing control circuit **1** controls the row driver unit **5** and, via the selector circuit **3**, the column driver unit **6**.

The correction operation circuit **2** receives the column driver control signal **S203**, the display data **S201**, and the row driver control signal **S202** which are output from the timing control circuit **1**. Then, the correction operation circuit **2** calculates an increment or decrement of an effective voltage value, which will be actually applied, from an effective voltage value which is intended to be applied to the liquid crystal panel **7**. The correction operation circuit **2** determines correction data **S301** which is appropriate for each column electrode **72** and outputs the correction data **S301** to the selector circuit **3**.

The selector circuit **3** receives the column driver control signal **S203** and the display data **S201** output from the timing control circuit **1** and the correction data **S301** output from the correction operation circuit **2**. In a display period, the selector circuit **3** switches between the display data **S201** in a display period and the correction data **S301** in a correction period. The display data **S201** or the correction data **S301** is output as a data signal **S401** from the selector circuit **3** to the column driver unit **6**. The selector circuit **3** also outputs the

column driver control signal **S203** to the column driver unit **6**.

The power source circuit **4** generates voltages V1, V2, V3, V4, and V5 required for driving the row and column driver units **5** and **6**. The voltages V1 and V5 are used as selection voltages in scanning row electrodes **71**. The voltage V3 is used as a non-selection voltage in scanning the row electrodes **71** and as an off voltage corresponding to the correction data **S301** applied to the column electrodes **72**. The voltages V2 and V4 are used as on or off voltages corresponding to the display data **S201** applied to the column electrodes **72**, or on or off voltages corresponding to the correction data **S301** applied to the column electrodes **72**.

The row driver unit **5** includes a plurality of row drivers **5-1**, **5-2**,..., and **5-Y**. Each of the row drivers **5-1**, **5-2**,..., and **5-Y** is used to apply a progressive scanning voltage to the row electrodes **71** of the liquid crystal panel **7** in accordance with the row driver control signal **S202** output from the timing control circuit **1**.

The column driver unit **6** includes a plurality of column drivers **6-1, 6-2,...,** and **6-X**. Each of the column drivers **6-1, 6-2,...,** and **6-X** is used to apply a signal voltage to the column electrodes **72** of the liquid crystal panel **7** in accordance with the column driver control signal **S203** and the data signal **S401** output from the selector circuit **3**.

The liquid crystal panel **7** is similar to one used in conventional LCD devices. The liquid crystal panel **7** includes N row electrodes **71**, and M column electrodes **72** which are provided in such a manner as to intersect the row electrodes **71**. The intersections are positioned in a matrix. A liquid crystal layer (not shown) is sandwiched between the row electrodes **71** and the column electrodes **72**. Each intersection corresponds to a pixel. The liquid crystal layer at each pixel performs display in response to the effective voltage value of a driving voltage applied between one row electrode **71** and one column electrode **72**.

Each circuit included in the LCD device **100** thus constructed will be described in more detail, where the liquid crystal panel **7** is of a SVGA type (800 columns ×

RGB × 600 rows).

Figures **2** and **3** are flowcharts showing an operation of the timing control circuit **1**. In Figure **2**, the synchronization signal **S102** and the display data **S101** which are input to the timing control circuit **1** are shown. In Figure **3**, the column driver control signal **S203** and the display data **S201**, which are output from the timing control circuit **1**, are shown.

In Figure **2**, a Vsync signal **51** and an Hsync signal **52** indicate a vertical synchronization signal and a horizontal synchronization signal, respectively, which are input to the timing control circuit **1** along with the display data **S101**. One period of the Vsync signal **51** is called one input vertical scanning period **T1**, and one period of the Hsync signal **52** is called one input horizontal scanning period **T2**. As to the display data **S101**, R(Red), G(Green), and B(Blue) color data are input to the timing control circuit **1** and transferred to subsequent circuits on a pixel-by-pixel basis in parallel at the same timing.

An enable signal **53** indicates an effective period

of the display data **S101**. The display data **S101** is effective at the effective period during which the enable signal **53** is at a High level. The enable signal **53** is kept at the High level during a period of time which is required for scanning 800 column electrodes, in one input horizontal scanning period **T2**, and becomes the High level 600 times in one input vertical scanning period **T1**, so that the display data of 800 columns × RGB × 600 rows is input to the timing control circuit **1**. A part of one input vertical scanning period **T1**, during which no effective data is input, is called a vertical blanking period **T3**.

In Figure **3**, an STA signal **61** is synchronized with the Vsync signal **51** (Figure **2**) and indicates the head of a frame. One period of the STA signal **61** is called one output vertical scanning period **T4**. In this case, one input vertical scanning period **T1** (Figure **2**) is equal to one output vertical scanning period **T4** (i.e., **T1=T4**).

An LP signal **62** is generated by reducing the period of the Hsync signal **52** (Figure **2**), which is a horizontal synchronization signal used in applying a signal voltage and a scanning voltage to the liquid crystal panel **7**.

One period of the LP signal **62** is called one output horizontal scanning period **T5**. A correction period **T7** which is equal to m horizontal scanning periods (where m is an integer more than 0 and less than L) is inserted to L output scanning periods **T5** (where L is an integer greater than or equal to 2) (step S1001 shown in Figure **1B**). One output horizontal scanning period **T5** is equal to one input horizontal scanning period **T2** multiplied by ((L-m)/L).

An Int signal **63** is a signal indicating the inserted correction period **T7**. Specifically, a period during which the Int signal **63** is at a High level indicates each correction period **T7**. An En1 signal **64** is a signal indicating the effective periods of the display data **S201** and correction data. Specifically, a period during which the En1 signal **64** is at a High level indicates each effective period. The En1 signal **64** is kept at the High level during a period of time which is required for scanning 800 column electrodes, in one output horizontal scanning period **T5**, becomes the High level 600 times in one output vertical scanning period **T4**, and becomes the High level the number of times a correction period is

inserted, so that the display data **S201** of 800 columns × RGB × 600 rows and the correction data are output. A part of one output vertical scanning period **T4**, during which no display data **S201** and no correction data are output, is called a vertical blanking period **T6**.

As described above, the timing control circuit **1** receives the synchronization signal **S102** and the display data **S101** (Figure **2**), and then generates the column driver control signal **S203** and the display data **S201** (Figure **3**) which are in turn output to the selector circuit **3**. Assuming that one correction period having one output horizontal scanning period **T5** is inserted into six output horizontal scanning periods **T5**, the description is continued below.

Referring to Figure **4**, the correction operation circuit **2** includes a display data line memory **21**, a distortion amount counter circuit **22**, a column direction counter **23**, a correction amount look-up table (LUT) **24**, an adder **25**, an operation line memory **26**, and a comparator **27**.

The display data line memory **21** stores the display

data **S201** for an n^{th} row, and outputs display data **S201A** for an $(n-1)^{th}$ row, which has been stored one output horizontal scanning period **T5** before, to the distortion amount counter circuit **22**.

The distortion amount counter circuit **22** receives the row driver control signal **S202**, the display data **S201** for the n^{th} row, and the display data **S201A** for the $(n-1)^{th}$ row. In the distortion amount counter circuit **22**, a column waveform change detection unit **29** sequentially detects changes in signal voltage which will be eventually applied to the liquid crystal panel **7** between the $(n-1)^{th}$ row and the n^{th} row for each column electrode **72**, based on the display data **S201** for the n^{th} row and the display data **S201A** for the $(n-1)^{th}$ row (S1002 shown in Figure **1B**). A counter **30** also included in the distortion amount counter circuit **22** calculates the total change in signal voltage over all of the column electrodes **72**, and outputs the result as an induced distortion count value **S204** to the correction amount LUT **24** (S1003 shown in Figure **1B**).

Specifically, for example, it is assumed that out of 800 columns × RGB, on 300 columns × RGB the signal

voltages are changed from the voltage V2 to the voltage V4, on 100 columns × RGB the signal voltages are changed from the voltage V4 to the voltage V2, on 250 columns × RGB the signal voltages are not changed from the voltage V2, and on 150 columns × RGB the signal voltages are not changed from the voltage V4. In this case, the induced distortion count value **S204** is equal to +600 $(=+1\times(300\times3)-1\times(100\times3)+0\times(250\times3)+0\times(150\times3))$, where signs + and - represent the direction of the changes in signal voltages, and where +1 is equal to a change from the signal voltage V2 to the signal voltage V4, and -1 is equal to a change from the signal voltage V4 to the signal voltage V2.

Induced distortion occurs in the scanning voltage, depending on the total change in signal voltages on all of the column electrodes **72**. Therefore, the induced distortion count value **S204** obtained by the distortion amount counter circuit **22** represents the amount of induced distortion in the scanning voltages.

The column direction counter **23** counts the number of column electrodes **72** in a lateral direction along the row electrodes **71**, and outputs the resultant count

value **S205** to the correction amount LUT **24**. In other words, the count value **S205** represents the position of a column electrode **72** in the lateral direction.

The correction amount LUT **24** receives the induced distortion count value **S204** output from the distortion amount counter circuit **22** and the lateral count value **S205** output from the column direction counter **23** and, for each column electrode, determines an induced distortion correction amount **S206** corresponding to the increment or decrement of an effective voltage value, based on an induced distortion look-up table (induced distortion LUT) **28**. The operation of the correction amount LUT **24** will be described with reference to Figures **5**, **6**, and **7**.

Figure **5** shows a table used for selecting an induced distortion correction variable in accordance with the count value **S205** representing the position of each column electrode **72** in the lateral direction along the row electrodes **71**. In the table of Figure **5**, vertical terms indicate frame numbers, horizontal items indicate the count values **S205**, and their intersections indicate the induced distortion correction variables to be

selected. A count value **S205** of "1" indicates the leftmost column electrode **72** of the liquid crystal panel **7**, and a count value **S205** of "800" indicates the rightmost column electrode **72** of the liquid crystal panel **7**.

As shown in Figure **5**, the count values **S205** range from "1" to "800", including 25 steps of 32 columns × RGB (here RGB counted as one). The frame number ranges from "1" to "8". Any one of the induced distortion correction variables A0 through A15 is allocated to a set of each step of the count values **S205** and each frame (S1004 shown in Figure **1B**). In this case, it is assumed that the row driver unit **5** (Figure **1A**) is provided at the left side of the liquid crystal panel **7**. Therefore, as the count value **S205** is increased, the induced distortion correction amount **S206** corresponding to the induced distortion correction variable is also increased. In other words, the induced distortion correction variables are designed so that the induced distortion correction amount **S206** is increased toward the right side of the liquid crystal panel **7**.

In this case, although there are only 16 steps A0

through A15 among the induced distortion correction variables, eight different sets of the induced distortion correction variables are periodically used on a frame-by-frame basis (one frame = one vertical scanning period). Therefore, the temporal average of the induced distortion correction amount can vary over about 100 or more steps, leading to smooth correction.

Figure **6** shows the induced distortion LUT **28** for correcting the increment or decrement of an effective voltage value due to induced distortion. In Figure **6**, vertical items indicate the induced distortion count values **S204**, the horizontal items indicate induced distortion correction variables, and their intersections indicates induced distortion correction amounts **S206** determined for each column electrode **72**.

As shown in Figure **6**, the induced distortion count value **S204** ranges from 0 to 2400 (=800 dots × RGB), including 38 steps of 64. The induced distortion correction variable ranges from A0 to A15, including 16 steps. An induced distortion correction amount **S206** is allocated to a set of each step of the induced distortion count value and each of the induced distortion correction

variables A0 through A15 (S1005 shown in Figure **1B**). In the induced distortion LUT **28**, the induced distortion correction amounts **S206** are increased as the induced distortion count value is increased.

In the induced distortion LUT **28**, the induced distortion correction values **S206** are represented as absolute values having no signs. Whether the induced distortion correction values **S206** are added or subtracted is determined in accordance with the increment or decrement of the effective voltage value for each column electrode **72**.

Figure **7** is a graph of the induced distortion correction variable (vertical axis) versus the count value **S205** representing the positions of a column electrode **72** in the lateral direction along a row electrode (horizontal axis). Although the induced distortion correction variables only ranges over 16 steps, i.e., from A0 to A15, the temporal average of the induced distortion correction variables over eight frames exists between the induced distortion correction variables as shown in Figure **7**. Such values lead to smooth correction with respect to the lateral direction.

As described above, the induced distortion correction amount **S206** for each column electrode **72** is determined in each horizontal scanning period in the correction amount LUT **24** and can correspond to the increment or decrement of an effective voltage value. The induced distortion correction amount **S206** is output to the adder **25**.

The adder **25** receives the induced distortion correction amount **S206** for each column electrode **72** and a previous correction amount **S207** which has been stored in the operation line memory **26**. Both the correction amounts **S206** and **S207** are added or subtracted together, and the result is stored in the operation line memory **26** as the previous correction amount **S207**.

During five horizontal scanning periods other than one horizontal scanning period provided as the correction period **T7** among six horizontal scanning periods, a calculated correction amount is stored as it is in the operation line memory **26** as the calculated correction amount **S207**. During the correction period **T7**, a calculated correction amount is not transferred as it

is to the operation line memory **26**. However, the calculated correction amount is transferred as a calculated correction amount **S208** to the comparator **27** before being stored in the operation line memory **26**.

Figure **8** is a table showing data conversion which is performed in the comparator **27**. The left column indicates the calculated correction amounts **S208** (Figure **4**) output from the adder **25**. The right column indicates the correction data **S301** (Figure **5**) which is applied to each column electrode **72** of the liquid crystal panel **7** via the column driver unit **6**. In the comparator **27**, the calculated correction amount **S208** received is converted into the correction data **S301**. The correction data **S301** is classified into 15 steps. A correction voltage having a different pulse width is applied to each column electrode **72** based on the correction data **S301**. An error ERR between the calculated correction amount **S208** and the correction data **S301**, which occurs in the conversion, is stored in the operation line memory **26** via the adder **25**. For example, when the calculated correction amount **S208** is "60", the corresponding correction data **S301** is "57". The difference of "3" between "60" and "57" is stored as

the error ERR in the operation line memory **26** via the adder **25**. The error ERR is added to or subtracted from the induced distortion correction amount **S206** (S1006 shown in Figure **1B**).

In this way, the correction operation circuit **2** generates the correction data **S301** for each column electrode **72**, and outputs the correction data **S301** to the selector circuit **3**.

The selector circuit **3** switches between the received display data **S201** and correction data **S301** in accordance with the Int signal **63** (Figure **3**), and outputs the exclusively selected data to the column driver unit **6**. For example, when the Int signal **63** is at the Low level, the display data **S201** is output to the column driver unit **6** during the High level period of the En1 signal **64**. When the Int signal **63** is at the High level, the correction data **S301** is output to the column driver unit **6** in the High level period of the En1 signal **64**. At the same time, the column driver control signal generated by the timing control circuit **1** is also output to the column driver unit **6**.

Figure **9** is a timing chart showing the waveform of a signal voltage applied to each column electrode **72**. In Figure **9**, an LP signal **62** and an Int signal **63** are signals for controlling the column drivers. As described above, when the Int signal **63** is in the Low period, the display data **S201** is transferred to the column drivers. When the Int signal **63** is in the High period, the correction data **S301** for each column electrode **72** is transferred to the column drivers. In the column drivers, the overall correction data **S301** which have been transferred in one horizontal scanning period **T5** are simultaneously applied to the respective column electrodes **72** in the correction period **T8**, in synchronization with the rising of the next LP signal **62**.

Figure **9** shows the waveforms of signal voltages applied to the column electrodes **72** at different positions in the lateral direction. Even when some signal voltages have the same waveforms in the display period, the signal voltages have correction voltages having different pulse widths which are applied to the respective column electrodes **72** in the correction period **T8**. The pulse widths of the correction voltages are optimally adjusted, depending on the positions in the

lateral direction along the row electrodes **71**. In the correction period **T8**, periods **T11** through **T14** are ones in which the signal voltage V2 is applied to the column electrodes **72**. Further, in the correction period **T8**, periods **T15** through **T18** are ones in which the signal voltage V4 is applied to the column electrodes **72**. In those periods, the effective voltage value is increased. In the correction period **T8**, periods **T21** through **T29** are ones during which the signal voltage V3 is applied to the column electrodes **72**. In those periods, the effective voltage value is not increased or decreased. Therefore, when the periods **T11** through **T14** in which the signal voltage V2 is applied to the column electrodes **72** and the periods **T15** through **T18** in which the signal voltage V4 is applied to the column electrodes **72** are variable for each column electrode **72**, the correction voltage can be optimized.

When the optimized correction voltage is applied to each column electrode **72** in the thus designed correction period, the induced distortion crosstalk can be smoothed and corrected optimally.

Since one horizontal scanning period is provided

as the correction period **T7** in six horizontal scanning periods, the overall correction amounts for five horizontal scanning periods can be converted together to correction data. Therefore, error can be reduced as compared with when correction is performed every horizontal scanning period.

In the foregoing, the correction period which is equal to one horizontal scanning period is provided every six horizontal scanning periods. Alternatively, the correction period **T7** which is equal to arbitrary m horizontal scanning periods may be provided every arbitrary L horizontal scanning periods. The correction voltages have different pulse widths corresponding to respective correction amounts. Alternatively, the correction voltages have different pulse amplitudes corresponding to respective correction amounts. As to the induced distortion LUT **28**, the correction amounts corresponding to the induced distortion count values are determined using the 16 induced distortion variables A0 through A15. An arbitrary number of induced distortion variables may be used. In the foregoing, 800 columns × RGB are divided into 25 regions each having 32 columns × RGB, and eight different sets of the induced distortion

correction variables which are applied to such regions depending on the lateral direction along the row electrodes **71** are periodically used on a frame-by-frame basis. Alternatively, an arbitrary number of regions and an arbitrary number of frames may be used. Further, the present invention is not limited to a liquid crystal panel having a pixel structure of a SVGA type (800 columns × RGB × 600 rows).

(Example 2)

Next, an LCD device and a driving method therefor according to Example 2 of the present invention will be described below. The LCD device of Example 2 has the same structure as that of Example 1 and further includes circuits which optimally correct blunt waveform crosstalk and the gradation phenomenon while correcting induced distortion crosstalk.

Blunt waveform crosstalk depends on at least either a change in signal voltage or a change in scanning voltage, but is independent of the position of each column electrode **72** in the lateral direction along the row electrodes **71** (Figure **1A**). The gradation phenomenon depends on the position of each column electrode **72** in

the lateral direction, but is independent of a change in signal voltage.

In Example 1, the induced distortion crosstalk depends on at least either a change in signal voltage or a change in scanning voltage as well as the position of each column electrode **72** in the lateral direction. Therefore, the circuit for correcting the induced distortion crosstalk can also be used to correct both blunt waveform crosstalk and the gradation phenomenon.

In Example 2, as shown in Figures **10A** and **11**, the correction operation circuit **2** further includes circuits in addition to the structure of Example 1 of Figures **1A** and **4**. In other respects, the LCD device of Example 2 is the same as that of Example 1. Figure **10B** is a flowchart showing an operation of an LCD device **300** of Example 2. Hereinafter, only differences with Example 1 will be described.

Referring to Figure **11**, a correction operation circuit **202** of Example 2 includes a display data line memory **21**, a distortion amount counter circuit **222**, a column direction counter **23**, a correction amount LUT **224**,

an adder **225**, an operation line memory **26**, and a comparator **27**. In contrast to the correction operation circuit **2** of Example 1 according to Figure **4**, the distortion amount counter circuit **222**, the correction amount LUT **224**, and the adder **225** are modified. In other respects, the correction operation circuit **202** is the same as that of Example 1.

Initially, a corrected period is provided in a manner similar to that of Example 1 (S1001 shown in Figure **10B**). The distortion amount counter circuit **222** is the same as that of Example 1 from a viewpoint of structure. The difference from Example 1 is that the distortion amount counter circuit **222** outputs a signal to the correction amount LUT **224**. Specifically, the distortion amount counter circuit **222** receives a row driver control signal **S202**, and the display data **S201** for the n^{th} row and the display data **S201A** for the $(n-1)^{th}$ row. Based on the display data **S201** for the n^{th} row and the display data **S201A** for the $(n-1)^{th}$ row, the column waveform change detection unit **29** sequentially detects a change in signal voltages from the n^{th} row to the $(n-1)^{th}$ row for each column electrode **72** (Figure **10A**), and outputs the results as a signal voltage change signal **S1101** to the

correction amount LUT **224** (S2001 shown in Figure **10B**). The counter **30** calculates the total of changes in signal voltages in all of the column electrodes **72** (Figure **10A**), and outputs the result as an induced distortion count value **S204** to the correction amount LUT **224** (S1003 shown in Figure **10B**).

The correction amount LUT **224** further includes a blunt waveform LUT **229** and a gradation LUT **230**, in addition to an induced distortion LUT **28A** as described in Example 1. The induced distortion LUT **28A** is used for correcting the increment or decrement of an effective voltage value due to induced distortion. The blunt waveform LUT **229** is used for correcting the increment or decrement of an effective voltage value due to a blunt waveform. The gradation LUT **230** is used for correcting the increment or decrement of an effective voltage value due to the gradation phenomenon.

Figure **12** shows the blunt waveform LUT **229** for correcting the increment or decrement of an effective voltage value due to a blunt waveform. In the blunt waveform LUT **229** of Figure **12**, a vertical item indicates an $(n-1)^{th}$ signal voltage, and a horizontal item indicates

an n^{th} signal voltage. The intersection of a vertical item and a horizontal item indicates a blunt waveform correction amount **S222** (Figure **11**). For example, when a signal voltage applied to a column electrode **72** is changed from V2 to V4, a blunt waveform correction amount **S222** for the column electrode **72** is determined as "4" (S2002 shown in Figure **10B**).

Figure **13** shows the gradation LUT **230** for correcting the increment or decrement of an effective voltage value due to the gradation phenomenon. In the gradation LUT **230** of Figure **13**, a vertical item indicates a count value **S205** representing the position of a column electrode **72** (Figure **10A**) in the lateral direction along the row electrodes **71**, and a horizontal item indicates a correction period number. The intersection of a vertical item and a horizontal item indicates a gradation correction amount **S223** (Figure **11**). A count value **S205** of "1" indicates the leftmost column electrode **72** of the liquid crystal panel **7**, and a count value **S205** of "800" indicates the rightmost column electrode **72** of the liquid crystal panel **7**.

As shown in Figure **13**, the count values **S205** range

from "1" to "800", including 25 steps of 32 columns × RGB (here RGB counted as one). The correction period number ranges from "1Ho" to "8Ho". The intersection of a step of the count values **S205** and a correction period number indicates a gradation correction amount (S2003 shown in Figure **10B**). In this case, it is assumed that the row driver unit **5** (Figure **1A**) is provided at the left side of the liquid crystal panel **7**. Therefore, as the count value **S205** is increased, the gradation correction amount **S223** is also increased. In other words, the gradation correction amounts **S223** are designed so as to be increased toward the right side of the liquid crystal panel **7**.

In this case, eight different sets of gradation correction amounts for the count values **S205** are periodically used on a correction-period-by-correction-period basis. Therefore, the temporal average of the gradation correction amounts can vary in smaller steps, leading to smooth correction.

The increment or decrement of an effective voltage value due to the gradation phenomenon is smaller than the increment or decrement of an effective voltage value due

to a blunt waveform or due to induced distortion. Therefore, a correction amount is not determined every horizontal scanning period, but is determined every correction period.

Further, an induced distortion correction amount **S221** is determined in a manner similar to that of Example 1 (S2004 shown in Figure **10B**). As described above, in the correction amount LUT **224**, the induced distortion correction amount **S221** for correcting the increment or decrement of an effective voltage value due to induced distortion, the blunt waveform correction amount **S222** for correcting the increment or decrement of an effective voltage value due to a blunt waveform, and the gradation correction amount **S223** for correcting the increment or decrement of an effective voltage value due to the gradation phenomenon are determined for each column electrode **72** (Figure **10A**) and output to the adder **225**.

In the adder **225**, the received induced distortion correction amount **S221**, blunt waveform correction amount **S222**, and gradation correction amount **S223** are added or subtracted together. Similar to Example 1, an error ERR is added to or subtracted from an induced

distortion correction amount corresponding to the next correction period (S1006 shown in Figure **10B**), and a correction voltage is applied to each column electrode **72** (Figure **10A**) based on correction data (S1007 shown in Figure **10B**).

The operation line memory **26** and other elements thereafter have the same circuit structure and operation as those of Example 1.

A look-up table for correction amounts corresponding to blunt waveforms is not limited to the blunt waveform LUT **229** of Figure **12**. A look-up table for correction amounts corresponding to gradation phenomena is not limited to the gradation LUT **230** of Figure **13**. These look-up tables may be optimally designed in accordance with properties of a liquid crystal panel used.

As described above, in the present invention, a means for optimally correcting induced distortion crosstalk due to a change in signal voltage is provided, thereby suppressing induced distortion crosstalk and improving the display quality of an LCD device.

Further, a correction period which is equal to m horizontal scanning periods are provided in L horizontal scanning periods, where L is an integer greater than or equal to 2 and m is an integer more than 0 and less than L. Therefore, correction amounts corresponding to (L-m) horizontal scanning periods can be accumulated, thereby reducing a correction error.

Furthermore, it is possible to detect a bluntness amount of a signal voltage waveform due to a change in signal voltage. Blunt waveform crosstalk can be suppressed by performing correction in accordance with the bluntness amount in the correction period. A means for generating a correction voltage which is varied every one or more column electrodes is provided. Therefore, the gradation phenomenon can be suppressed by providing the correction voltage in the correction period.

Various other modifications will be apparent to and can be readily made by those skilled in the art without departing from the scope and spirit of this invention. Accordingly, it is not intended that the scope of the claims appended hereto be limited to the description as set forth herein, but rather that the claims be broadly

construed.